19. Fly Investigations Reports.—III. Investigations into Stable Manure to check the Breeding of House-Flies, made during the year 1915 for the Zoological Society of London. By WINIFRED H. SAUNDERS \*.

[Received March 19, 1916 : Preliminary report read by Prof. H. MAXWELL LEFROY, November 9, 1915.]

#### INTRODUCTION.

An extensive series of experiments was made in June and July for the purpose of finding a treatment for fresh stable manure, which would be effective in checking the breeding of House-flies, and which could be safely employed for agricultural purposes.

Owing to the increased price of borax, which before the war was the only substance in use for the purpose, the need for a treatment at a lower cost was pressing for military purposes, for farmers, horticulturists, and manure contractors.

Many practical obstacles arose in working out the solution of this problem.

Although many tons of manure were accumulated in artillery and cavalry camps, it was impossible to get a sufficient quantity conveyed to convenient trial-grounds owing to the difficulty of transport. A small amount was purchased, and, later, facilities were granted at the Army Veterinary Hospital, Woolwich, and on market-garden premises at Brentford, where stable manure was dumped. Experiments on manure, to test the action of various liquids upon flies and maggots, were carried out at Woolwich and at Brentford, and those on plants at the Royal Horticultural Society's Gardens, Wisley, at Messrs. Sutton's, Reading, and at the Horticultural College, Swanley.

This work on manure treatments was suggested and designed by Professor Maxwell Lefroy, under whose guidance all the experiments have been carried out.

#### A. MANURIAL EXPERIMENTS.

Experiments on fresh stable manure were made along two lines :--

- 1. To test the action of vapourisable liquids upon maggots present in the manure.
- 2. To test the action of substances as repellents to flies when applied to the surface of manure heaps.

Experimental heaps of definite sizes and shapes were constructed, and the strength of each application was in proportion to the cubic area of the manure.

\* Communicated by Prof. H. MAXWELL LEFROY, M.A., F.Z.S.

## The Application of Maggot Poisons.

The following liquids miscible in water were used :-

Miscible Tetrachlorethane (Westoran). Miscible Fusel oil 1 °/<sub>0</sub>. ,, Pyridene 10 °/<sub>0</sub>. ,, 5 °/<sub>0</sub>. Soluble Tar oil. Higher Pyridene bases. Neutral Blast-furnace oil. Miscible oil, Heavy. ,, , Light.

## Methods.

1. Several small heaps, each of 10 cubic feet, were treated with Westoran and Miscible Fusel oil. Each heap was 1 foot high on a soil foundation, which was covered with peat-moss litter.

				Results on the 3rd day		
				Westoran.	Miscible Fusel Oil, 1 %.	
1. One quart of	1 oz. (	diluted	to 40 ozs.	Alive.	Alive.	
solution						
mixed inti- mately with	2 ozs.	,,	>>	**	Escaped.	
the manure.	4 ozs.	,,	"	Dead.	Alive.	
2. Maggots put at ± from	1 oz.	,,	>>	Alive.	Escaped.	
the bottom,	3 ozs.	,,	,,	Many dead.	,,	
of liquid	5 ozs.	37	,,	Dead.	22	
at $\frac{2}{3}$ .						
3. Control					Escaped.	

2. Typical span-shaped manure-heaps of 220 and 110 cubic feet treated with Westoran and Miscible Fusel oil respectively.

1 quart of solu-	' Westoran.	Miscible Fusel Oil, 1%.
tion to every	In the strength of 2 ozs.	In the strength of 4 ozs.
10 cubic feet	in 40 ozs. water (5%).	in 40 ozs. water $(10^{0}/_{0})$ .
of manure. Maggots put in	Resu	ılts.
three positions.	In 24 hours maggots in	In 24 hours maggots all
The liquid was	the centre dead;	living.
sprayed on as	maggots near the top	Third day some living,
the heap was	pupated; maggots at	others pupated.
made up.	the bottom, near the	Fifth day all dead.
	edge, alive.	

3. 5-foot cubes of manure (125 cubic feet) were treated with Westoran, Miscible Pyridene, Kerosene, higher Pyridene bases, and Cresol.

Liquid poured down			
a hole in the centre	Westoran	n. Miscib	le Pyridene.
25 ozs. diluted to		In 24 hours :	•
$3\frac{1}{8}$ gallons with	All dead.	All dead	1.
the quart per 10		In 2 days :	
cubic feet) = $5 \frac{0}{0}$ .	Dead near the	centre. Dead ne	ear the centre.
Maggots put in six			
positions.			
Liquid sprayed as stack was built in	Kerosene.	Higher Pyridene Bases.	Cresol.
the strength of			
24 ozs. diluted to	•	In 24 hours :	
$4\frac{1}{2}$ gallons (= $1\frac{1}{2}$	3 lots dead.	3 lots dead.	2 lots dead.
- ozs. to 1 quart per			
10 cubic feet).		In 2 days :—	
Maggots put in four	4th lot dead.	4th lot dead.	3rd lot dead.
positions			

4. Two heaps, each on a 5-foot-square base, 5 feet high with a  $l_{\frac{1}{2}}$ -foot-square top, treated with :—

Miscible Pyridene 5 %, 1 quart to 2 gallons of water. ,, Heavy, 2 quarts to 2 gallons of water.

Results.

Liquid was poured down the centre in the strength of 1 quart diluted to 2 gallons with water. Maggots were put in two positions. In a few days flies were emerging from both heaps. The heaps were opened, and the oil was found to be concentrated in the centre. Both were hot, and puparia were present in the bottom edges of the heap and in the soil under the edges.

The manure used for the above experiments was not flyinfected; maggots enclosed in gauze were put into the heaps.

## The Application of Fly-Deterrents.

The following non-miscible liquids were used :---

Neutral Blast-furnace oil. Blast-furnace Creosote. Green oil. Tar oil and Pyridene. Mineral oil and Pyridene.

They were applied by :---

(a) Mixing with soil in the proportion of one part liquid to forty parts soil. The soil was piled into a cone, and the oil

poured into a depression at the top and thoroughly incorporated with the soil by the "cone-and-quarter" method. The mixture was spread over the surface of the manure, forming a layer 1 inch thick.

(b) Treating the soil on which the manure rested, as well as the surface, by sprinkling the plain oil or spreading oiled soil.

(c) Sprinkling plain oil evenly over the surface of the manure.

### Methods.

I. Three manure-heaps, each on a base  $6\frac{1}{2}$  feet square, rising to 3 feet in the centre, were treated with Neutral Blast-furnace oil. Blast-furnace Creosote, and Green Tar oil mixed with dry soil in the proportion of one part oil to 40 parts soil, spread evenly over the surface, forming a layer 1 inch thick. Maggots were put under the treated layer on the fourth day.

#### Results.

Neutral Blast- furnace Oil.	Blast-furnace Creosote.	Green Tar Oil.	
Living after 2 days.	Dead in 2 days.	Dead in 24 hours.	

11. Four manure-heaps, each on a base 7 feet square, rising 3 feet to a top 3 feet square, were treated with :--

> Green oil. Green oil and Pyridene. Neutral Blast-furnace oil.  $\bigg\}^{\frac{1}{2}}$  gallon to 10 gallons of soil. Control.

The mixture was spread evenly over the surface. All the manure was infected.

## Results.

In three days larvæ were found dead in the treated heaps. In six days the Control heap contained large maggots. The treated heaps remained immune.

III. Four manure-heaps, each on a base 4 feet 6 inches square, rising 18 inches in the centre, were treated with :-

- 1. Mineral oil and Pyridene.  $\begin{cases} \frac{1}{4} \text{ gall. sprinkled over base.} \\ \frac{1}{4} \text{ gall. with 10 galls. soil on surface.} \end{cases}$
- 2. Mineral oil and Pyridene.  $\frac{1}{4}$  gall. with 10 galls. soil on surface only.
- 3. Tar oil and Pyridene.....  $\frac{1}{4}$  gall. with 10 galls. soil on surface only.
- 4. Tar oil and Pyridene......  $\begin{cases} \frac{1}{4} \text{ gall, with 10 galls, soil on surface only,} \\ \frac{1}{4} \text{ gall, sprinkled over base.} \end{cases}$

The manure contained many full-grown larva, but the heaps were too small to heat.

### Results.

Flies emerged from the mineral-oil heaps through places where straw prevented the treated soil from lying evenly. They were

not seen emerging from the Tar-oil-treated heaps, and these were covered with muslin. Flies emerged later in small numbers.

Tar Oil and	Tar Oil and	Mineral Oil and	Mineral Oil and
Pyridene ;	Pyridene ;	Pyridene :	Pyridene;
Top and Under.	Surface only.	Top and Under.	Surface only.
Flies emerged,	Few flies emerged,	Many flies	Flies emerged,
no pupæ present	pupe found in	emerged, no	some pupæ m
in the soil under-	the soil under-	pupæ in the	the soil.
neath.	neath.	soil.	

Results show that the Tar oil prevents the maggots from migrating into the soil below the manure-heap. While forming a barrier to larvæ, and acting as a deterrent to flies, it does not prevent flies which emerge from pupæ present in the manure from escaping through gaps provided by the straw of long manure.

N.B.—Maggots placed on soil mixed with (1) Green Tar oil, (2) Neutral Blast-furnace oil burrowed into it away from the light, and were dead in ten minutes.

IV. Four manure-heaps, each on a base  $6\frac{1}{2}$  feet square, rising 3 feet in the centre to a point, were treated with :—

Neutral Blast-furnace Oil. Blast-furnace Creosote. Green Tar oil. Control.  $\begin{cases} \frac{1}{2} \\ \frac{1}{2}$ 

The treated soil was spread evenly over the heaps. Maggots were placed in each and the temperatures recorded. In areas of about 95° F. the larvæ were dead in all but the Control heap.

#### Results.

In five days the Control heap was infected while the treated heaps remained immune. Observations showed that conditions were favourable to breeding, but that flies were repelled from the treated heaps.

V. Five heaps, each on a base 7 feet square, rising 3 feet to a top 3 feet square, were treated with :---

Neutral Blast-furnaee oil. Blast-furnaee Creosote. Green Tar oil. Miseible oil and Pyridene.

## Regults.

In four days maggots were found in the heaps treated with Blast-furnace Creosote and Miscible oil and Pyridene. These two stacks were destroyed. For ten days no maggots were found in the other two, although conditions such as moisture, temperature, etc. seemed suitable for breeding, and untreated manure in the same condition became infected.

VI. Five heaps of long manure on a base 7 feet square, rising 3 feet to a 3-foot square, were treated with :---

Mineral	oil a	nd Pyric	lene	1	gallon	with	40	gallons	of soil.
"	,,	,,		$\frac{1}{2}$	,,	> 2	20	>>	,,
Tar oil	and P	yridene	•••••	1	,,	,,	40	"	**
,, Control	.—Soi	,, 1 only,		$\frac{1}{2}$	,,	,,	20	22	,,

#### Results.

In two days maggots were found dead on the surface of the Tar-oil-treated heaps, and a live one was wriggling in the full light on the top. In four days the heaps contained large dead maggots, and the Control contained full-grown maggots and puparia. Flies had evidently been laying in the Control. The treated heaps were still free in ten days.

VII. Three manure-heaps on a base 7 feet square, rising 3 feet to a 3-foot square. The manure was long but not infected. They were treated with :---

Mineral oil and Pyridene  $10 \frac{0}{0}$ .  $\begin{cases} \frac{1}{2} \text{ gall. sprinkled over the base.} \\ \frac{1}{2} \text{ gall. with } 20 \text{ galls. soil on surface.} \end{cases}$ Tar oil and Pyridene  $10 \frac{0}{0}$ . Ditto.

#### Results.

In five days the Control and Mineral-oil heaps contained maggots, but none were present in the Tar-oil one. It was warm, moist, and appeared very suitable. Observation showed that flies came readily to the heaps and that Pyridene appears to be attractive, but the attraction is temporary.

VIII. One large heap of mixed manure on a base 9 yards by 7 yards was treated with a watering of pure non-miscible liquids. Seven gallons were used for a light watering. This was at the same rate as that used in soil-treatment, showing that an application of 1-inch-thick treated soil at one part in forty is about equivalent to a light watering with the liquid.

N.B.—There was a Control heap to each set of experiments which was examined for eggs and maggots, and where the conditions proved unsuitable for breeding no conclusions were drawn from the Control heaps.

### B. PLANT TRIALS.

All the substances used in the manurial experiments were tested on plants in open plots, in pots, and in frames.

#### I. PLOTS.

1. At Wisley, Blast-furnace Creosote, Neutral Blast-furnace

HOUSE-FLY INVESTIGATIONS.

oil, and Green Tar oil were mixed with soil at the rate of 1 in 40, and used with manure in the proportion of 10 gallons of oiled soil to 100 gallons of manure. Ten barrow-loads of treated manure was dug into each plot sized 44 feet by 8 feet. French beans and turnips were sown.

## Results.

	Gross weight of crop in lbs		
	Turnip.	Bean.	
Blast-furnace Creosote	$. 243\frac{1}{2}$	$20\frac{1}{2}$	
Control	. 270	16	
Neutral Blast-furnace oil	$. 215\frac{1}{2}$	18	
Control	$. 232\frac{1}{2}$	$17\frac{1}{2}$	
Green Tar oil	$. 170\frac{1}{2}$	18	

2. At Messrs. Sutton's, Reading, who supply the following report, substances were tested on mustard, being a quick-growing crop :---

Fifteen plots in all were treated, and the experiments were carried out in two series, Series I. consisting of Plots 1 to 10, and Series II., Plots numbering from 11 to 15. Each plot was about 1 square pole in area. The land on which these experiments were conducted was previously under mangel plants, and all of it had precisely a similar treatment.

Series I.—The heaps of dung for these plots were dug in on June 26th, 1915, and the mustard sown on June 28th; the following tables serve to indicate the character of the dressings with which the dung was treated, the dates on which the seed germinated in each plot, and the respective merits of the plots at the dates mentioned.

Series II.—The dung in this case was dug in on August 13th, 1915, and the mustard sown on the following day; the results will be found in the tables already alluded to.

It is most satisfactory that in both series not a single crop should have failed, and that consequently it may be assumed that dung treated with the chemicals employed by Professor Maxwell Lefroy may be used for manurial purposes without hesitation.

#### Series I.

Control No. 1 (untreated).

Aa	Miscible	oil.	Heavy	,	24.07	es dib	ited t	0 41 0	allons
A 1		, o,	1100.1					0 - 2 8	
AD.	23	,,	"		48	.,,	,,	9	
Ba.	"	,,	Light		24	,,	,,	4 <u>1</u>	•,
Bb.	,,	,,	,,		48	,,	,,	9	,,
Ca.	,,	,,	' P '	·····	<b>24</b>	,,,	,,	$4\frac{1}{2}$	,,
Cb.	,,	,,	,,		48	,,	,,	9	,,
Da.	,,	,,,	'F'	••••••	<b>24</b>	,,	,,	$4\frac{1}{2}$	,,
Db.	,,	,,	,,		48	,,	,,	9	,,
Ea.	Westora	n	or M	liscible	<b>24</b>	,,	,,	$4\frac{1}{2}$	,,
	Tetrac	chloi	ethane	•				_	

## MISS W. H. SAUNDERS ON THE

Dates of Notes.	Notes to Trials.
July 5th, 1915.	Germination showing in each and fairly general in all.
July 10th	'Control' and six following are all uniformly good and practi- cally no difference between any.
	Da and Db not quite so even as the preceding, not uniform in growth, gappy.
	Ea in much the same condition as 'Control.'
July 24th,	No real difference between 'Control' and six following lots. Da and Db continue the least satisfactory. Ea good lot and equal to 'Control.'
July 31st. "	' Control ' and six following lots still much alike. Da the weakest, but not really poor.
Aug. 13th	The plots were inspected by Professor Maxwell Lefroy and Dr. Stenhouse Williams.

## Series II.

Manure received August 13th and plots sown August 14th.

	Control No. 2.
	Ac. Manure oil No. 1 with earth.
	Bc, ,, No. 2 ., ,;
	Cc. " " No. 3 " .,
Dates of Notes.	Notes to Trials.
Aug. 21st, 1915.	All plots germinated satisfactorily.
Aug. 31st, .,	Not much difference between 'Control,' Bc, and Cc. Ac not quite so strong.
Sept. 4th, "	'Control' and Bc the two strongest. Ac the weakest.
Sept. 11th, "	All four lots are good, but of the four Ac is slightly the weakest.
Sept. 18th, "	Now all very strong and good, and little difference to be seen between any.

# II. FRAMES.

1. At Swanley, melons and cucumbers were planted in frames and grown on the French system. Each plant was planted in soil over a cubic foot of treated manure. The treatments were :---

Westoran.	
Miscible Fusel oil 1º 0.	
Miscible Pyridene.	
Miscible oil, Heavy.	
Miscible oil, Light.	5 ozs. diluted to one quart
Kerosene.	per 10 cubic feet.
Higher Pyridene bases.	<b>^</b>
Cresol.	
Heavy Tar oil and Cresol.	
Neutral Blast-furnace oil	
Non-Miscible Tar oil.	5 ozs. to 10 cubic feet.
Nou-Miscible Pyridene.	5 oz-, to 10 cubic feet.
Control.	

#### Results.

All the plants grew to maturity and bore normal crops, with the exception of the Westoran-treated one, which died.

2. Melons planted in soil over one cubic foot of treated soil and manure and grown in a French frame. The treatments were :—

Neutral Blast-furnace oil. Blast-furnace Creosote. Green Tar oil.

All gave normal results.

3. Melons planted in soil over a hot-bed of manure treated with Westoran in the strength of 2 ozs. diluted to one quart with water per 10 cubic feet. The plants were grown on the French system, and the results were normal.

4. Cucumbers were planted in soil over a hot-bed of manure treated with Miscible Pyridene  $10 \,^{\circ}/_{\circ}$  in the strength of 2 ozs. diluted to one quart per 10 cubic feet. They were grown on the French system with normal results.

N.B.—In the case of 3 and 4 the manure used was treated a fortnight previous to planting. In all the other experiments the manure was used immediately after treatment, so that nothing was lost. In actual practice a certain amount would be lost before use.

III. Pors.

1. At Wisley, white mustard was sown in 7-inch pots on loam and treated manure in equal parts. They were kept in a cool frame and shaded.

 1. Treated with
 30 c.c. of the mixture.

 2.
 ,,
 ,,
 150
 ,,
 ,,

 3.
 ,,
 ,,
 300
 ,,
 ,,

#### Results.

Miscible oil, Heavy	Rapid germination.	Good crop.
,, ,, Light	<b>3</b> 2 <b>3</b> 2	<b>33 33</b>
Miscible Pyridenc, Series 1 and 2	<b>33 33</b>	,, ,,
"	Uneven "	Poor "
Miscible Fusel oil, Series 1	2 <b>3</b> 33	<b>3</b> 7 <b>3</b> 7
,, ,, ,, ,, 2 and 3	Even "	Good "
Westoran, Series 1	»» »»	32 33 <sup>7</sup>
" " 2 and 3	Poor "	Poor "
Kerosene.		
Higher Pyridene bases.		
Cresol.	Good "	Good "
Heavy Tar oil and Cresol.		
Neutral Blast-furnace oil.		

The plants were grown for two months, and at the flowering stage all the results were equal and even with the Control. The Westoran treatment resulted in a checked thin crop, but the plants reached maturity.

2. Cape Pelargoniums and Adiantums (maidenhair ferns) were reported from 60's into 5-inch pots with equal parts loam and treated manure. The treatments used for mustard in Experiment 1 were repeated on twenty-two species of *Pelargonium* and on *Adiantum henslowianum*.

All grew quite healthily, and at the end of seven weeks the treated plants looked as well as the Control.

3. At Swanley, melons were potted with a compost of equal parts treated manure and loam, and grown in a temperature of  $60-80^{\circ}$  F. For each treatment 1 quart of liquid was used with 4 ozs. and 3 ozs. of the chemical.

Westoran at both strengths killed the plants, but those treated with the following behaved normally compared with the Control. They were kept until pot-bound :—

> Miscible Fusel oil. Miscible Pyridene 10<sup>0</sup><sub>0</sub>. Miscible oil, Heavy. Miscible oil, Light. Miscible Pyridene 5<sup>0</sup>/<sub>0</sub>. Kerosene. Higher Pyridene bases. Cresol. Carbon Tetrachloride.

Heavy Tar oil and Cresol. Fusel oil. Neutral Blast-furnace oil. Tetrachlorethane. Miscible Pyridene 15 % Molar. Soluble Tar oil. 4 Blast-furnace Creosote. Green Tar oil.

4. Cucumbers, for which the methods of No. 3 were employed, were treated with :—

Non-miscible Tar oil, Non-miscible Pyridene

with perfectly normal results.

#### Conclusions.

The experiments show that the investigations led to two very successful treatments :---

- 1. The surface-dressing of manure with Green Tar oil or with Neutral Blast-furnace oil and soil.
- 2. The application of Tetrachlorethane.

Both treatments successfully kill maggots in the manure and are harmless to plants.

The Tar oil has a permanent effect in being resistant to rain, while the effect of Tetrachlorethane lasts only while the liquid vapourises, and in time the poisonous vapour escapes.

The treatments began with the series of vapourisable liquids which led to the surface applications. Although these treatments are more satisfactory than any hitherto recommended, it is admitted that there are still some doubtful points in connection with the relation of the migration of the larvæ to the condition of the manure due to chemical action other than changes in temperature. For the early experiments infected manure was not obtainable; maggots enclosed in gauze were placed in different positions in the stacks. When House-flies became abundant naturally infected manure was used.

The Tar-oil treatment is recommended for large accumulations of manure, either in military camps or for horticultural purposes, in the proportion of one part of oil to forty parts of soil. One gallon of liquid mixed with forty gallons of soil covers 100 square feet. The oils are products of the first distillation of tar. For large quantities the price is 1s. per gallon, making the cost of the treatment 1d. per cubic yard for surface treatment only and 2d. per cubic yard for treatment of the ground and of the surface.

The value of manure is 1s. 9d. the cubic yard.

Treat the manure which is added to a heap every five days, and if fresh ground is to be covered, when adding to a heap, oil the ground first.

Maggots present in manure which is stacked on soil dressed with a Tar oil cannot escape into the ground to pupate. The manure ferments normally when treated with the oil, and the maggots perish in the treated soil to which they are driven, or they pupate in a stack which is cool (Experiment III.). That a manure-stack treated with Green oil or with Neutral Blastfurnace oil will remain immune to fly-attack has been confirmed by Experiments II., IV., V., VI., and VII., where in each case the Control became infected.

That the treatment is harmless to plants is shown by the results of Plant Trial I. (Plots) and III. (Pots) and Messrs. Sutton's Series II., Ac and Cc.

The vapour treatment with Tetrachlorethane, in the miscible or in the pure form, is recommended for small quantities of manure and for fresh manure used for hot-beds in the strength of 2 ozs. to 10 cubic feet of manure.

Tetrachlorethane is a heavy liquid, specific gravity 1.6 and boiling-point 147° C. It is non-inflammable and commercially available. The price of pure Tetrachlorethane is 35s. per cwt. and that of Westoran 52s. per cwt. That a manure-stack treated with Tetrachlorethane will effectively kill maggots has been proved by Experiments I., II., and III., and that used with manure at 2 ozs. per 10 cubic feet is safe for plants, by Trials 3 (Frames) and Messrs. Sutton's Series I., Ea.

It is worth noting that all the treatments have been tested in intensive culture with satisfactory results at the strengths recommended.